Benchmark on rejuvenators, all rejuvenators are not equal

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Presentation outline

- Research objectives
- Methods and materials
- Results
- Conclusions
- Discussion
Research objectives – aspects to considered in this presentation

1. HSE & Waste considerations
2. Physical properties
3. Influence on aged binder characteristics
4. Influence on functional behaviour of asphalt mixtures
5. Assessment on full scale trials

Therefore, this presentation is focused on laboratory results with the aim to methodologically evaluate various products.
Materials (described in this presentation)

- **Rejuvenators** (13 different products)

- **Binders**
  - Recycled binders (includes repeated recycling), **100 % recycling**
  - Paving grade bitumen
  - Reclaimed Asphalt binders
Composition according to Safety Data Sheet

- Refined rapeseed oil
- Mixture of resins, waxes, polymers
- Residues (petroleum), vacuum
- Mixture of vegetable oils
- Fatty acid derivates
- Rosins esters, fatty acid and vegetable oil
- Mixture of modified alkylamidopolyamine and vegetal oils
- Polyol ester, tall and turpentine oils
- Fatty acid methyl ester
- Aromatic extract
- Mixture of vegetable oils
- Product which contains waxes 1
- Product which contains waxes 2

Note: the sequence of rejuvenators is purposely skewed and does not fit the designation in presentation
Methods (described in this presentation)

• Testing of rejuvenators
  – Rejuvenators as such (physical properties)
  – Efficiency (via change of binder rheological properties)

• Testing of binders
  – Susceptibility to aging
  – Aging methods (RTFOT, 3xRTFOT, PAV, 2xPAV)
Evaluation of rejuvenators as such
Evaluation of rejuvenators as such

1. Flash point
2. Loss of weight (rejuvenators/binders)
3. Dynamic viscosity
4. Fume emission evaluation
5. HSE – REACH classification
6. …
Some rejuvenators have lower flash point than required on binders (≥ 230 °C).

There is no requirement or a recommended limit in Europe.
**Results – rejuvenators and recycled binders – loss of weight**

Clear relationship between rejuvenators’ and recycled binders’ loss of weight

![Graph showing the relationship between rejuvenators' and recycled binders' loss of weight.](image)

Note: **results are base binder dependent** (reference 50/70 – mass loss + 0.04 %)

Some rejuvenators emits lots of fumes during RTFOT – organoleptic detection.
Rejuvenators’ partial conclusions

• Some rejuvenators have **lower flash point than required on binders** (a need to consider a viable way of dosing. e.g. prior drum, pug mill, binder...)

• Good **correlation on** rejuvenators’ and rejuvenated binders’ **mass loss**.

• Some rejuvenators can require **constant heating** during pumping at plant.

• Some rejuvenators emits **significant** amounts of **fumes** (health issue).
Rejuvenators’ effectiveness
Rejuvenators’ effectiveness, general information

Effectiveness is dependent on the parameter used to assess it. → higher dosing generally needed to restore viscous components.

Almost all rejuvenators can restore empirical properties (same category after recycling) → not possible to tell the difference.

Source: Recommendation for the use of rejuvenators in hot and warm mix asphalt production [EAPA]
Rejuvenators’ effectiveness, influence of boundary conditions

![Graph showing dosing percentage against temperature for different testing frequencies and rejuvenators.]

**Dosages to restore G* to initial values**

**Different dosing for each temperature domain**

Note: example of one rejuvenator and one testing frequency

- Aged binder R&B 61.6°C, pen. 23 (0.1mm)
- Original binder R&B 48.0°C, pen. 56 (0.1mm)
## Rejuvenators’ effectiveness, influence of boundary conditions

<table>
<thead>
<tr>
<th>Rej.</th>
<th>Calculated optimum dosages to rejuvenate aged binder</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>Boundary conditions</td>
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<tr>
<td></td>
<td>$G^*$, 60 °C, 1.59 Hz</td>
</tr>
<tr>
<td>A</td>
<td>8.3</td>
</tr>
<tr>
<td>B</td>
<td>8.4</td>
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<tr>
<td>C</td>
<td>11.9</td>
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<tr>
<td>D</td>
<td>8.6</td>
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<td>I</td>
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<td>J</td>
<td>8.9</td>
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<tr>
<td>M</td>
<td>13.2</td>
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</tbody>
</table>

**Fresh binder before aging**

- $G^* @ 60 °C$ a 1.59 Hz $\approx 2.3$ kPa
- $G^* @ 25 °C$ a 0.4 Hz $\approx 266.2$ kPa
- $G^* @ 15 °C$ a 10 Hz $\approx 14170.0$ kPa

**Aged binder to rejuvenate**

- $G^* @ 60 °C$ a 1.59 Hz $\approx 16.6$ kPa
- $G^* @ 25 °C$ a 0.4 Hz $\approx 1460.0$ kPa
- $G^* @ 15 °C$ a 10 Hz $\approx 28690.0$ kPa

*Note: the sequence of rejuvenators is purposely skewed and does not fit the designation in presentation*
Rejuvenators’ effectiveness, influence of rejuvenator type

- Aged binder R&B 61.6°C, pen. 23 (0.1mm)
- Original binder R&B 48.0°C, pen. 56 (0.1mm)
Rejuvenators’ effectiveness, effect of aged binder type

- Reclaimed Asphalt binders (non-modified) pen 12 to 25 (0.1mm)

- Efficiency not affected by initial penetration

- Possible to use calibration curves
Rejuvenators’ effectiveness, effect of aged binder type

- Reclaimed Asphalt binders (non-modified)
- Reclaimed Asphalt binder modified, pen. 13 (0.1mm)

Be aware of different effects on anyhow modified binders
Rejuvenators’ effectiveness, partial conclusions

- Rejuvenators have **different ability to restore** visco-elastic properties.
- **Rejuvenated binders** might fit 50/70 category, the viscoelastic behavior **can be very different** (not necessarily worse) **compared to paving bitumen**.
- **Efficiency not affected** much by aged **binder source** (non-modified binders)
- No rejuvenator was able to fully restore the initial properties no matter what dosage used.

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Is it at all reasonable to expect or require the full recovery???

It is probably not needed (not possible even), we should look for balance. **Design dosage based on intermediate parameters** (penetration, VET, G*), keep the benefit of elasticity while having lower stiffness. **Dosing need to be verified and adjusted based on mixture testing.**
Recycled binders’ susceptibility to aging
• Most paving bitumens within the PI limits (-1.5 to 0.7)
• PI is an informative parameter in EN 12591 (temperature susceptibility)
Results – susceptibility to ageing, reclaimed asphalt binders

Reclaimed asphalt binders (non-modified) are positioned also within PI limit.
Results – susceptibility to aging

Modified Retrieved asphalt binders can be positioned differently

- Impact on recycling
- Impact on binder classification

Attention should be paid to completely different PI, which remains even after rejuvenation.
Results – reclaimed asphalt binders recycling

- Rejuvenators A and C
- Dosing 4 % and 12 %
- Reclaimed Asphalt b. R3 (non-modified)

Possible to recycle the reclaimed asphalt binders into paving grade categories
Results – reclaimed asphalt binders recycling

- Rejuvenators A and C
- Dosing 4 % and 12 %
- Reclaimed Asphalt b. R3 (non-modified)
- Reclaimed Asphalt b. R7 (modified)

Not possible to rejuvenate into paving grade categories
Rejuvenated PMB classified as PMB??
Results – susceptibility to aging, empirical properties

50/70 prolong aging period (RTFOT+2xPAV)
Results – susceptibility to aging, empirical properties

- Rejuvenator M
- Dose 10.9 %
- RTFOT+2xPAV

Recycled binder can maintain the PI limits after aging, even lessen the impact of aging (lower SP, higher penetration)
Results – susceptibility to aging, empirical properties

- Rejuvenator B
- Dose 6.5 %
- RTFOT+2xPAV

Recycled binder can be positioned very differently and even propagate aging
Rejuvenated binders’ aging, partial conclusions

• **Long-term aging** is needed to differentiate rejuvenators (RTFOT alone is not sufficient).

• Some rejuvenators **accelerates aging**.

• High aged PMB might not be possible to rejuvenate into paving grade categories – use of **PMB classification**.
Remarks

• Be aware that these information are based on 100 % recycling.

• Functional properties of asphalt mixtures are decisive for the industry.
• Industry shall define **what is expected from rejuvenators**. (position paper – a good step taken)

• Should be introduced **any requirements on rejuvenators** in Europe?

• Should be define **what is** considered as rejuvenators’ **optimum dosage**?
Thank you

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Rejuvenators’ effectiveness, evaluation via functional approach

Use of Black Space to evaluate the behavior

- Green — 50/70 paving bitumen, pen 56 (0.1 mm)
- Blue (X) — recycled (6.5 %), categorized as 50/70, pen 58 (0.1 mm)
- Red (Y) — recycled (8.5 %), categorized as 50/70, pen 58 (0.1 mm)
Rejuvenators’ effectiveness, influence of rejuvenator type

Interrelation between dosing according to different parameters

Penetration is reference = 1.0
Results – re-recycling

- Rejuvenator M
- Dose 10.9 % (1st)
- Dose 13.2 % (2nd)

Comparable behaviour compared to paving bitumens
Results – re-recycling

- Rejuvenator I
- Dose 6.2 % (1st)
- Dose 6.3 % (2nd)

Completely different behaviour compared to paving bitumen